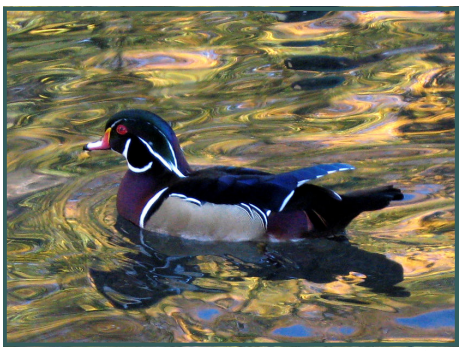
South Sound Science Symposium
Linking Threats to Indicators

Terry Liberty



Bonnie Liberty

For more information, go to: www.psp.wa.gov/southsoundscience.php

USING MODELS TO COMPARE AND PRIORITIZE ACTIONS IN PUGET SOUND– WHO'S MODELING WHAT AND WHY?

Anise Ahmed[1], Skip Albertson[1], Bohyun Bahng[2], Ben Cope[3], Mitsuhiro Kawase[2], Tarang Khangaonkar[4], Greg Pelletier[1], Mindy Roberts[1], Brandon Sackmann[1], and Zhaoqing Yang[4]

[1]Washington Department of Ecology, [2]University of Washington, [3]US Environmental Protection Agency, [4]Pacific Northwest Laboratories

Computer models are helping to unravel what makes Puget Sound tick in critical areas like Hood Canal and South Puget Sound. Models are powerful tools that can synthesize available information and provide a virtual laboratory to enhance our understanding of water quality and to test alternative management strategies for addressing problems. Models complement existing monitoring programs and could refine future programs. Monitoring data are required to drive the models and to test how well they describe current conditions. However, models also can provide context to monitoring programs— Is a monitoring station in a stagnant region? Are two stations so similar that one could be eliminated?

These case studies represent examples from key parts of Puget Sound, including Hood Canal, South Puget Sound, and Budd Inlet. In each case, the models help us understand how fundamental circulation and water quality processes work so that we can tease out how humans have altered those processes. We need to know not only who contributes what, but what effect do human contributions have on the health of Puget Sound? Models are the only way we can link specific management actions with potential benefits.

Many organizations have developed models of Puget Sound for a variety of purposes. Diagnosing problems and recommending recovery actions for Puget Sound requires multiple models, just as diagnosing human health problems sometimes requires multiple doctors or additional opinions. When multiple models confirm similar findings, our confidence in the results increases. When models conflict, often they identify areas of greatest uncertainty. Many marine modelers in the Puget Sound region cooperate through an ad hoc group called the Puget Sound Marine Environmental Modeling Consortium (PSMEM-C), whose goal is to share information and tools to improve modeling tools for Puget Sound.

South Puget Sound

SOUNDTOXINS: A HARMFUL ALGAL BLOOM AND *VIBRIO* MONITORING PROGRAM FOR PUGET SOUND

Keri Baugh, Nick Adams, Brian Bill, Rohinee Paranjpye, Jason Miller, Carla Stehr, and Vera Trainer - NOAA Fisheries

SoundToxins is a monitoring program designed to provide advanced warning of harmful algal bloom (HAB) and *Vibrio parahaemolyticus* events. Advanced warnings of HABs enable early or selective harvesting of shellfish and provide fish farmers the ability to reduce the detrimental effects of HABs on fish. SoundToxins draws its strengths from a diverse partnership of shellfish farmers, fish farmers, environmental learning centers, volunteers and Native American Tribes. The project goals are to determine: 1) which environmental conditions promote the onset and blooming of HAB species and increased concentrations of *Vibrio parahaemolyticus* and 2) which combination of environmental factors might be used for early warning. Sampling is performed at 12 sites throughout Puget Sound and weekly water samples are analyzed for temperature, salinity, macronutrients, chlorophyll a, marine toxins (paralytic shellfish toxins and domoic acid), and phytoplankton species with a focus on the HAB species *Alexandrium catenella*, *Dinophysis* spp., *Pseudo-nitzschia* spp., and *Heterosigma akashiwo*. Water samples from five of the sites are also analyzed for the presence and concentration of *Vibrio parahaemolyticus*. In addition to the weekly shored-based samples, offshore collections were made on the University of Washington's PRISM cruise in August 2008, providing surface and depth measurements for a spatial snapshot in Puget Sound. In 2008, *Pseudo-nitzschia* was observed at significant densities but low domoic acid was found throughout the sampling region with maximum concentrations in Sequim Bay. Currently, no monitoring is performed by the Washington State Department of Health for *Dinophysis* toxins even though the organism has been found at several sites and at significant densities. The poten-

tial danger for *Dinophysis* toxins needs to be fully assessed for the Puget Sound region.

CREATING A NEARSHORE SALMON HABITAT ASSESSMENT FOR COMMENCEMENT BAY AS AN UNDERGRADUATE SERVICE LEARNING EXPERIENCE

Bonnie Becker and Bridget Mason - University of Washington Tacoma

This quarter, University of Washington Tacoma students will be participating in a local service learning project to help managers plan regional conservation efforts. The TESC332 Conservation Biology in Practice class will conduct a nearshore salmon habitat assessment for Commencement Bay, based off of a similar assessment done by Pentec Environmental for the Key Peninsula, Gig Harbor, and Islands area in 2003. Students will complete a series of labs to introduce them to GIS, habitat assessment models, data mining and data collection in the field, culminating in a final report and presentation to local stakeholders. Habitat quality will be compared between the east and west sides of Commencement Bay as well as among sites around the county. This project will prepare environmental studies and science majors for conservation careers as well as provide valuable data to local managers.

EFFECTS OF INTERTIDAL GEODUCK AQUACULTURE ON BENTHIC MOBILE FAUNA: PROPOSED RESEARCH

Rana Brown – The Evergreen State College

Geoduck aquaculture has been a lucrative and controversial business for decades in Washington State. Recently, as more intertidal lands are converted to geoduck farms, concerns have been raised over the effects of these farms on local ecosystems. In 2007 the state legislature passed Bill 2220 which created a program within Sea Grant (University of Washington) to identify research goals and then to conduct research as needed. One area of concern is how these farms, and the way in which they are operated, are affecting biodiversity in Puget Sound. One argument is that these farms are (or eventually become) a monoculture, and that ultimately they are lowering biodiversity in areas in which they are located. This proposed research project will investigate these claims and attempt to determine if geoduck farming operations affect biodiversity of benthic mobile fauna. Two stages of geoduck aquaculture will be tested for differences. One treatment group will be that which has recently been planted and has tubes with blanket netting. The other will be a bed that is in grow-out phase that has no predator protections. Testing these two treatments should allow me to identify if the associated structures and/or geoduck presence are having any impacts on the local community structure. Research locations will be in southern Puget Sound with sampling beginning in May 2009 and ending in October 2009.

TRACKING TREND IN FECAL POLLUTION IN SOUTH PUGET SOUND SHELLFISH GROWING AREAS

Tim Determan - Washington State Department of Health

The Washington State Department of Health developed a Fecal Pollution Index (FPI) to track status and trend in fecal pollution Puget Sound. I will use the FPI to rank South Puget Sound shellfish growing areas according to fecal pollution impact in 2008. I will also show ten-year trend in six growing areas with extensive histories of remedial action (Burley Lagoon, Henderson Inlet, Eld Inlet, Nisqually Reach, Oakland Bay, and North Bay).

THE SEDIMENT QUALITY TRIAD INDEX: AN INDICATOR FOR PUGET SOUND AND A BASELINE UPDATE (1997-2003)

Margaret Dutch, Sandra Weakland, Edward Long, Kathy Welch, and Valerie Partridge - Washington State Department of Ecology

The Sediment Quality Triad Index (SQTI) was developed by the Puget Sound Assessment and Monitoring Program's (PSAMP) Sediment Component to facilitate calculation of the spatial extent of degraded sediments throughout Puget Sound. In 2006, the Washington State Department of Ecology's Marine Sediment Monitoring Team completed SQTI and spatial extent calculations for Puget Sound sediments collected from 1997-2003. Subsequently, a refined data analysis has been conducted, and spatial extent calculations have been revised for Puget Sound sediments. The number and percent of stations, and area (km^2) and percent of area with *high*, *intermediate/high*, *intermediate/degraded*, and *degraded* sediments for eight PSAMP sediment monitoring regions (including the South Puget Sound region), five strata defined by geologic features and exposure to human activity, and Puget Sound-wide. These four categories are based on the Sediment Quality Triad of chemical contamination, toxicity, and quality of benthic invertebrate communities. The Sediment Quality Triad Index, and the spatial extent calculations derived from them, has been listed as an indicator of water quality health in Puget Sound by the Puget Sound Partnership. These revised spatial extent calculations, based on the SQTI, will be the basis for comparison of spatial change (km^2) in sediment quality over time for Puget Sound sediment monitoring regions, strata, embayments, and Puget-sound wide.

MOVEMENT PATTERNS OF COASTAL CUTTHROAT TROUT *(ONCORHYNCHUS CLARKI CLARKI)* IN SOUTH PUGET SOUND, WASHINGTON 2006-2007

Sarah R. Hague and Fred Goetz – University of Washington

Few studies have focused on the anadromous life-history form of coastal cutthroat. Migratory pathways of coastal cutthroat, especially short-distance estuarine migrations, are even less understood. Previous studies on coastal cutthroat trout primarily focused on freshwater systems and described spawning and rearing characteristics, population structures, and genet-

ics of the freshwater life-history forms. This study collected baseline data on movements and nearshore habitat use of two sample populations (Totten-Little Skookum Inlets and Squaxin/Hope Island) of anadromous coastal cutthroat trout in South Puget Sound using acoustic tracking technology. A total of forty cutthroat were captured in their marine environment, surgically implanted with acoustic transmitters and tracked for eight months via a network of multi-channel acoustic receivers placed throughout the deep South Sound area of South Puget Sound. Analysis suggested a difference in movement patterns and distances traveled between sample populations; however, the overall trend for both sample groups was a movement towards the extreme terminal areas of the study area. A significant difference ($P<0.05$) in movements in relation to size-class was found in both populations. Analysis of associations between movements of coastal cutthroat trout and chum salmon migrations suggested the Totten-Little Skookum Inlets group displayed movement patterns that closely followed both adult and juvenile chum salmon migrations. However, movement patterns displayed from the Squaxin/Hope Island group did not reveal this same behavior, indicating a lack of large-scale movements from broader and deeper-water areas into more defined inlets in response to temporally discrete chum salmon migrations. Data also suggested that anadromous coastal cutthroat in South Puget Sound may have a home range distinct from Central and North Puget Sound and may heavily utilize specific habitats, such as Skookum Inlet, during the fall and winter months.

MAINTAINING LENTIC-BREEDING AMPHIBIANS IN URBANIZING LANDSCAPES OF THE PUGET SOUND/GEORGIA BASIN ECOSYSTEM: DO CURRENT REGULATIONS PROTECT POND-BREEDING AMPHIBIANS?

Marc Hayes, Tim Quinn, and Joanne Schuett-Hames - Washington Department of Fish and Wildlife

Urbanization is an increasingly prominent issue in the terrestrial landscape of the Puget Sound/Georgia Basin. We used the Northern Red-legged Frog (*Rana aurora*) as a case study to evaluate the efficacy of existing guidelines and regulations in addressing amphibian conservation in urbanizing areas. *Rana aurora*, endemic to the transboundary Pacific Northwest, may serve as an umbrella species for co-occurring lentic-breeding amphibians since it requires specific arrangements of terrestrial and aquatic habitat extending over a relatively broad area. Relatively brief late-winter/early-spring use of lentic aquatic habitats for reproduction is the best-studied aspect of *R. aurora* seasonal life history. We know less about terrestrial habitat use in summer, and even less about overwintering habitat. However, we are beginning to recognize that on an annual basis adult frogs move long distances that can span nearly 5 km in breadth. New data indicate that migration movements to and from breeding sites invariably extend over 300 m, and frequently over 1-km in length. It is likely that guidelines and regulations for protecting habitat in urbanizing areas within the geographic range of this frog will fail for two reasons. First, existing regulations requiring wetland buffers often protect breeding sites from local disturbance but not from disturbances occurring across the broader landscape that affect breeding habitat hydrology, water quality, and vegetation structure. Second, terrestrial habitat outside the wetland buffer is largely ignored, even though frogs may use this habitat for an overwhelming portion of each year. Given the nature of urbanization in the Pacific Northwest, we conclude that even if *R. aurora* can persist at sites over the short term, larger-scale habitat connectivity and perhaps interconnected habitat networks, as required to support metapopulations, may be necessary to maintain urban populations of *R. aurora* over the long term. If local jurisdictions want to maintain *R. aurora* and other amphibians, like western toads (*Bufo boreas*), that use broader spatial scales than historically realized in urban areas, then they need to revise their guidelines and regulations. These revisions should include protecting sufficient terrestrial habitat that is connected to breeding habitat, and consider larger-scale habitat networks to facilitate inter-population dispersal and migration.

THE EXTENT OF HATCHERY-ORIGIN FISH AMONG FALL CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) OBSERVED IN SOUTH PUGET SOUND TRIBUTARY STREAMS

Kevin Kennedy[1], Scott Steltzner[2], and Amy Cook[3]
[1]Washington Department of Ecology, [2]Squaxin Island Indian Tribe, [3]The Evergreen State College

Chinook salmon *(Oncorhynchus tshawytscha)* have been observed in small numbers, for over 50 years, in many of the small tributary streams that feed into Puget Sound south of the Tacoma Narrows Bridge. Observations do not predate the release of hatchery-reared Chinook salmon throughout the region, so the origin of the Chinook presently observed in these streams, as well as any potential role they could serve in recovery efforts of the Puget Sound Chinook Salmon Evolutionary Significant Unit, remain unknown. The extent of hatchery-origin fish among the Chinook salmon observed in South Puget Sound tributary streams was assessed using existing hatchery release and spawning ground survey records. Hatchery mark rates from the Regional Mark Information System (RMIS) Database were compared with mark sampling recovery rates from the Washington Department of Fish and Wildlife Spawning Ground Survey Database to see if similar mark rates existed between the two groups. Although the hatchery mark rates exceeded mark recovery rates of fish observed during spawning ground surveys in most instances, mark sampling recovery data revealed that the majority of carcasses observed at three of the four streams with adequate sample sizes had clipped adipose fins or coded wire tags, suggesting an extensive presence of hatchery-origin fish among the Chinook salmon observed at these streams. This might indicate that these fish are primarily present due to previous or current releases of hatchery Chinook salmon in South Puget Sound. If this assumption is correct, designating these streams as critical habitat would not prove beneficial in aiding

the recovery of the Puget Sound Chinook salmon ESU and could pose unintended consequences for the co-managers, Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes, responsible for managing the salmonids present in these streams.

A 59 YEAR RECORD OF ENVIRONMENTAL STREAMFLOWS IN THE DESCHUTES RIVER

John Konovsky - Squaxin Island Tribe

Among smaller rivers and streams in South Sound, the Deschutes River at Rainier has the longest period of record for a USGS stream gage . The first full water year began in 1950 and the gage ran continuously until 1975 and then again after 1999; records in the intervening period are spotty. The Squaxin Island Tribe contracted with Hydrologic Services Co. in Bellingham to extend the record by filling in the missing data. The extension was based on flow data from a Weyerhaeuser Co. gage upstream of Rainier using a period of record between 1975 and 2004.

The extended dataset was then analyzed with software developed by The Nature Conservancy for indicators of hydrologic alteration. Daily mean flows were classed as extreme low flow (< 34 cfs), low flow (34-305 cfs), high flow pulses (306-2660 cfs), small floods (2661-3993 cfs) or large floods (> 3993 cfs). A graph of the discharge record classed by environmental streamflow is available.

If the data is divided into two groups of water years, 1950-88 and 1989-2008, and compared statistically, the following changes in hydrology are significant:

Environmental Parameter (means)	1950-88	1989-2008
Daily flow	260 cfs	253 cfs
Extreme low flow (1 day minimum)	29 cfs	23 cfs
Extreme low flow timing	September 20	September 14
High flow peak	721 cfs	674 cfs
High flow timing	January 28	January 31
High flow frequency	11 events/ year	10 events/year
Small flood peak	3165 cfs	3113 cfs
Small flood duration	32 days	35 days
Small flood timing	January 13	December 30
Small flood frequency	0.7/year	0.6/year
Large flood peak	4518 cfs	4859 cfs
Large flood timing	January 10	January 11

Other environmental parameters like frequency of extreme low flows and large floods were not significantly different between the two periods, although extreme events occurred with more regularity between 1989 and 2008.

The data analysis suggests there has been a shift in streamflow from high flow pulses and small floods to large floods. Extreme low flows and small floods occur earlier in the water year. There is less overall flow and in particular, a reduction in extreme low flow volumes. The reduction in low flow volume is consistent with data reported in the Deschutes River TMDL Technical Report. The reports cites a decrease in the 7Q10 discharge from 26 cfs (1949-69) to 21 cfs (1991-2001).

SOUTH SOUND DATA FROM THE TRIBAL CANOE JOURNEY

John Konovsky - Squaxin Island Tribe

The annual Canoe Journey of the Coast Salish Nations of Washington state and British Columbia added a scientific twist last summer. Five canoes, including one pulled by the Squaxin Island Tribe Canoe Family through South Sound, towed water quality probes to provide daily, longitudinal profiles of temperature, salinity, dissolved oxygen, turbidity and pH of the marine waters along the route. The Tribal Journey Water Quality Project is a partnership between the Coast Salish skippers, pullers and the USGS.

The South Sound portion of the journey began at Arcadia Boat Launch and ended near Ketron Island on July 15, 2008. On the next day, the journey traveled on to Point Defiance. The data presents a first-of-its-kind snapshot of 2008 summer water quality conditions. Plans are to continue the data collection during the 2009 Canoe Journey to the Suquamish Tribe's homeland.

FECAL COLIFORMS (FC) ON INTERTIDAL SEDIMENT CREATE SUMMER CRITICAL PERIODS FOR INDICATOR BACTERIA AROUND WESTERN WASHINGTON

John Konovsky[1], *Levi Keesecker*[1], *and Anise Ahmed*[2]
[1]Squaxin Island Tribe, [2]Washington State Department of Ecology

FC residing on intertidal sediment in upper Oakland Bay form a secondary source of indicator bacteria. Under windy conditions, they re-suspend into the water column; the effect is most pronounced in late summer. The sediment FC population increases from about May through September, holds steady until December, and then declines again. The higher the FC concentration on the sediment surface, the higher the water column FC. These results were duplicated in a TMDL model developed for Oakland Bay by DOE—a regression between wind speed and FC levels was ten times better at predicting observed FC concentrations in the marine water than using tributary loading alone.

A review of the DOH Shellfish Program water quality database

established the location of additional shellfish beds around Western Washington with similar conditions. Nine other sites were identified where both 1) the summer geometric means exceeded the fall-winter-spring means by at least 5 cfu, and 2) the summer geometric means exceeded the 14/43 NSSP standard for safe shellfish harvest. They were: Bay Center, North River, & Moclips on the coast; Lynch Cove, Dosewallips, Skagit Bay, North Bay, Henderson Bay, and Nisqually Reach in Puget Sound.

Other researchers found that when supplied with sufficient organic nutrients, *E. coli* can grow in seawater almost as well as rich lab media. Nutrients may propagate through benthic fluxing and seasonal patterns of plankton growth and marine snow deposition to support substantial FC populations on sediment July-December. One season of data suggests a positive intra-annual correlation between daily concentrations of inorganic nitrogen species in the water column and sediment FC.

Inter-annually, one variable source of nutrients is shellfish mortality. A comparison of seven years of shellfish survival data in upper Oakland Bay with summer mean water column FC concentrations identified an inverse correlation between the two variables—the greater the shellfish mortality and likely release of nutrients, the higher the mean FC concentrations. This suggests one pathway to drive a link between nutrient and FC concentrations.

Further research combined with a model of the influence of wind and wave action may better explain intra-annual and inter-annual variation in observed summer FC concentrations around Western Washington.

HARBOR SEAL DIET: A TOOL TO MONITOR THE PUGET SOUND GEORGIA BASIN FOOD WEB

Monique Lance and Steven Jeffries - Washington Department of Fish and Wildlife

Traditional techniques that are used to assess fish populations in the Puget Sound Georgia Basin include conducting sampling trawls, use of side scan sonar and for salmon, collection of run size data from fisheries, at dams, fish weirs and hatcheries. A novel way to assess fish populations is to examine diet of the resident harbor seal, an abundant and ubiquitous marine predator that is highly mobile with a primarily piscivorous generalist diet. We have studied harbor seal diet for the past 10 years in three regions: South Puget Sound, Hood Canal and North Puget Sound. These areas are distinct geographically and have unique attributes and yet we have found for all three areas that adult salmonids are important seasonally and a gadid species and Pacific herring dominate the diet year round. As adult salmon migrate into the region and become abundant, harbor seals forage primarily on salmon (range 25–67% frequency of occurrence). For gadids, seals prey primarily on Pacific tomcod in south Puget Sound, Pacific hake in Hood Canal and walleye pollock in North Puget Sound/San Juan Islands. These data correlate well with gadid composition in each region and provide a good indicator of availability. Herring are a significant year round component of seal diet in all three areas. Herring form dense aggregations and with their high caloric content, they are important energetically for seals (and seabirds). The status of herring stocks in these regions is mixed with several populations of critical status. One of the major risks to the survival of herring that has been identified is increased predation by seals with populations in excess of 15,000 animals. Conservation efforts and resources need to be devoted to declining fish populations such as herring that play vital roles in the Puget Sound Georgia Basin food web. As a top-level carnivore, harbor seal diet also provides information about contaminant accumulation in the ecosystem. Harbor seal diet appears to reflect fish availability and can be used to help understand food web dynamics, to track changes in resource availability and provide insights into the impacts on marine ecosystems by human activities.

THE IMPORTANCE OF SITE SELECTION AND TREATMENT INTENSITY FOR LARGE WOODY DEBRIS PROJECTS IN THE MASHEL RIVER, TRIBUTARY TO THE NISQUALLY RIVER (WASHINGTON, USA)

Florian Leischner[1], Kimberlie Gridley[2], and Chris Ellings[1]
[1]Nisqually Indian Tribe, [2]South Puget Sound Salmon Enhancement Group

The Mashel River, the largest tributary to the Nisqually River (Washington, USA) accessible to anadromous salmon, has been a major focus for freshwater habitat restoration by the Nisqually Tribe and its partners. Large-woody debris structures were used to establish and promote high quality in-stream habitat and floodplain reconnection in three projects completed since 2002. The initial project, at the confluence of the Mashel and Nisqually Rivers, used minimal funding and materials to establish channel complexity in a wood depleted system. The other two projects used large quantities of wood in engineered and constructed log jams. Four log jams were placed strategically within a town park to work within the confines of existing infrastructure and land use, and another eight log jams were constructed within undeveloped preserved land without treatment constrictions. This paper covers the project implementation, outcome, and effectiveness of the three projects that are vastly different in size, scope, and site characteristics but located on the same river.

ESTIMATING INDIVIDUAL DETECTION PROBABILITY AND ABUNDANCE FOR STREAM-ASSOCIATED AMPHIBIANS USING MULTIPLE VISIT SURVEYS

Eric Lund, Aimee McIntyre, and Marc Hayes - Washington Department of Fish and Wildlife

Most stream-associated amphibian studies have used count data to index abundance. Inferences based on comparisons of these indices over time or space assume that detection prob-

ability remains constant. As part of an experimental study to examine the effectiveness of different riparian buffer prescriptions on non-fish-bearing stream basins, we utilized a recently developed statistical method to estimate individual capture probability and abundance using data collected from in-stream amphibian surveys repeated over multiple sampling occasions during the pre-harvest interval. We conducted these surveys for focal amphibians (*Ascaphus truei*, *Rhyacotriton*, and *Dicamptodon*) in 45 30-m plots in 18 study basins across southwest Washington state, using a longitudinal light-touch method whereby all moveable objects on the streambed that were gravel-sized or larger were overturned. We sampled plots on 3 visits spaced 1-4 days apart in July-August 2008; 31 of the 45 plots were sampled again during a second set of 3 visits in September 2008. We estimated detection probabilities to be less than 0.40 for all 3 taxa. Repetition of these multiple pass surveys following completion of harvest treatments will allow for a comparison of detection probabilities over time as well as incorporation of the probabilities into unbiased estimates of abundance before and after harvest. We describe additional applications of this methodology and future research plans.

POINT DEFIANCE TO NISQUALLY RIVER DELTA HISTORIC SEDIMENT SOURCE MAPPING – AN APPROACH TO IDENTIFY AND PRIORITIZE PROCESS-BASED RESTORATION OPPORTUNITIES IN THE PUGET SOUND REGION

Andrea MacLennan, Jim Johannessen, and Stephanie Williams - Coastal Geologic Services

Process-based restoration has been recognized as the ideal means of restoring Puget Sound nearshore environments. Processed-based restoration attempts to restore and protect these self-sustaining processes that support the ongoing maintenance of habitats on a landscape scale. Coastal geomorphic processes create and maintain the nearshore habitats upon which many Puget Sound species of concern rely, including forage fish spawning areas, and juvenile salmonid rearing and migratory habitats, among others. Eroding bluffs (commonly referred to as "feeder bluffs") contribute sediment to net shore-drift cells (along shore sediment sub-systems), replacing sediment that is continuously transported to maintain down-drift habitats such as spits and pocket estuaries.

CGS has developed a mapping criteria that documents the current and geomorphic conditions within each drift cell (alongshore sediment sub-system). The historic geomorphic mapping approach measures the level of impairment to coastal geomorphic processes and ranks the relative quality of historic sediment sources. Current geomorphic conditions (feeder bluff mapping) has been applied to over 650 miles of Puget Sound shore, and historic conditions have also been mapped across over 250 miles of shore. CGS most recently applied this method for the South Puget Sound Salmon Enhancement Group to the reach of shore from Pt Defiance to the Nisqually River Delta. Results of the mapping approach highlighted reaches of shore that were once active sediment sources for the beach and nearshore and therefore the best potential areas to target process-based restoration or enhancement such as beach nourishment or side-casting of landslide colluvium from the BNSF rail line. By comparing results of current and historic conditions mapping, restoration/enhancement areas were prioritized at multiple scales – across the entire reach of shore, drift cells and individual bluff units. These methods will be presented in detail along with the results of the recent mapping and prioritization effort for the shore from Pt Defiance to the Nisqually River Delta. In addition, examples of additional restoration and conservation opportunities that were identified using the results of this method that are now moving forward towards implementation throughout other areas of Puget Sound, will be presented.

QUANTITATIVE COUNTS OF *ALEXANDRIUM CATENELLA* CYSTS, SEDIMENT ANALYSES, AND 210PB DATING DOWN CORE OF A LONG CORE FROM QUARTERMASTER HARBOR, PUGET SOUND, WASHINGTON

Julie Masura[1] and James Postel[2]
[1]University of Washington Tacoma, [2]University of Washington Seattle

Alexandrium catenella, a dinoflagellate known to cause paralytic shellfish poisoning, has existed in parts of Puget Sound and Georgia Basin for years. *A. catenella* spends part of its life cycle as a cyst in the sediment before germinating to become a free-swimming dinoflagellate. *A. catenella* cysts in surface sediments are used to determine the present spatial distribution of this organism, while cyst concentrations in sediment cores can be used to evaluate historical presence and temporal variability. An initial NOAA/ECOHAB study in 2005 found that Quartermaster Harbor (QMH) has the highest abundance of *A. catenella* cysts anywhere in Puget Sound. This poster presents the results from the analysis of a 112 cm sediment core collected in the middle of QMH during March 2005 as part of the original project. Other properties presented include grain-size and total organic content analyses, as well as age from Pb-210 dating. The greatest abundance of cysts is located at the top of the core, and cysts decrease exponentially down core. Understanding the historical distribution of *A. catenella* cysts is important in tracing its spread throughout the Salish Sea from Georgia Basin to South Puget Sound.

THE CONTRIBUTION OF WORKING FORESTS AND THE FORESTS AND FISH ADAPTIVE MANAGEMENT PROGRAM IN SUSTAINING ECOSYSTEMS FOR AMPHIBIAN ASSEMBLAGES IN THE PACIFIC NORTHWEST

Aimee McIntyre, Julie Tyson, Marc Hayes, Timothy Quinn, and Eric Lund - Washington Department of Fish and Wildlife

Washington State has over 14 million acres of forestland and is the second largest lumber producer in the nation. Much of this land (40%) is private- and state-managed forestland covered under the Forests and Fish Habitat Conservation Plan

(HCP). This HCP, a collaborative effort between federal, state, tribal and county governments, and forest landowners, was designed to comply with the federal Endangered Species Act for aquatic and selected riparian-dependent species, support a harvestable supply of salmon, meet Clean Water Act requirements, and maintain the viability of the timber industry. Unique to the HCP was the development of an adaptive management program promoting studies to evaluate and improve forest practices for the protection of public resources. We have been conducting amphibian-related research on managed lands in western Washington as part of this program since 2001. Our overarching objectives are to address the efficacy of current forest practices, and where consistent with other HCP goals, improve forest practices for protection of amphibians in headwater landscapes.

Our focal study addresses the efficacy of the riparian management prescription for non-fish-bearing streams. Harvest treatments are being applied to 18 study basins in a before- and after-treatment control impact design. This design, which will enable distinguishing treatment-specific responses among stream-associated amphibians, is currently in its treatment phase. Pre-treatment efforts have resulted in over 12,000 amphibian detections representing 17 species. A second study underway examines differences in amphibian response to different levels of riparian shading as a result of harvest. These studies will inform approaches for forest practices that will help maintain amphibians in headwater streams. We are encouraged by the persistence and relative abundance of amphibians in these forests for two key reasons: 1) many of these forests have been managed for over 100 years and have experienced multiple harvest rotations, and 2) forest practices have improved dramatically over the last 20 years to protect public resources. Studies like these, supported by the Forests and Fish Adaptive Management Program, are critical to understanding how to best meet the immediate need for wood fiber while protecting the long-term legacy of the Pacific Northwest.

PRELIMINARY BENTHIC INFAUNAL DATA AT PROPOSED GEODUCK AQUACULTURE LOCATIONS THROUGHOUT THE PUGET SOUND, WASHINGTON

Marlene Meaders, Jeffery Fisher, Scott Luchessa, Tim Sturtz, Karl Mueller, Greg Reub, and Matt Loxterman - ENVIRON International Corporation

Panopea abrupta (geoduck) is a unique organism within the Puget Sound. Although limited in global distribution, geoduck clams are relatively common throughout the local region. A baseline biological assessment study was launched in 2008 within Puget Sound at proposed new intertidal culture lands. This study has provided the opportunity to: (1) compare/ contrast local habitats that support geoduck clams across a relatively broad geography, (2) begin to develop a long-term dataset to determine if and how culture operations potentially change the surrounding environment, and (3) explore the diversity of Puget Sound benthic infauna. Evidence suggests that diversity within each proposed farm is dependent upon tidal elevation, local geomorphology, water movement, and species competition. The relationship among these factors has implications within the structure of the benthic infaunal community. The preliminary data also supports the general theory of functional feeding groups, which result in a consistent assemblage of predators, filter feeders, and deposit feeders. Explanations for deviations from these standard patterns are currently being explored.

THE PRESENCE OF *ALEXANDRIUM CATENELLA* IN RELATION TO ENVIRONMENTAL CONDITIONS IN QUARTERMASTER HARBOR, PUGET SOUND

Ashley Nepela, Cheryl Greengrove, and Julie Masura - University of Washington Tacoma

The dinoflagellate, *Alexandrium catenella,* is one of a few species of phytoplankton that causes a form of harmful algal bloom (HAB) known as Paralytic Shellfish Poisoning (PSP). *Alexandrium catenella* germinates from cysts in the sediment to mobile phytoplankton, thus allowing them to be filter fed by shellfish and their toxin to be concentrated in shellfish tissue, making the shellfish harmful to humans and other mammals that ingest them. In an earlier NOAA/ECOHAB study of *A. catenella* cyst concentrations in the surface sediments of Puget Sound, Quartermaster Harbor (QMH) was found to have two orders of magnitude higher concentrations than anywhere else in Puget Sound. This is consistent with frequent shellfish closures in this area by the Washington State Department of Health due to unsafe harvest levels of above 80 µg toxin/100 mg of tissue. In order to determine what environmental conditions favor the development of *A. catenella* in QMH we sampled a seven station transect longitudinally through the bay monthly starting in October 2006. CTD profiles of standard water properties were collected. In addition, discrete samples were collected and analyzed for chlorophyll-a, dissolved oxygen, nutrients and phytoplankton. The presence of *A. catenella* is seen as early as April and as late as October in the 2008 QMH quantitative plankton counts and although present, does not dominate any one month; *A. catenella* does not have to bloom in high concentrations to reach dangerous levels in shellfish. In this analysis, we have examined the environmental conditions, such as light, chlorophyll, oxygen, nutrients and stratification, associated with the presence of *A. catenella* in QMH. Determining the environmental conditions that most favor the excystment and growth of *A. catenella* is the first step in predicting harmful algal blooms.

MODELING DISSOLVED OXYGEN IN BUDD INLET AND CAPITOL LAKE

Mindy Roberts, Anise Ahmed, and Greg Pelletier - Washington Department of Ecology

Why bother modeling dissolved oxygen in Budd Inlet? People

who generally understand marine dissolved oxygen levels can identify the "usual suspects" contributing to low concentrations: elevated nutrient loading and sluggish circulation, for example. However, only a model can quantify effects from different sources, and only a model can be used to hypothesize what effect management actions might have if implemented. Nitrogen reductions, which will cost money, might substantially benefit DO in one area but may have no effect elsewhere. Models are important prioritization tools to ensure that management actions do not spend money targeting the wrong sources.

Ecology's linked Budd Inlet/Capitol Lake model provided a critical tool to understand what influences DO in the marine waters. Ambient monitoring in central Budd Inlet indicates that DO levels have declined steadily since monitoring began over 20 years ago, even though the largest wastewater discharger implemented denitrification in 1994 resulting in 90% decreases in summer nitrogen loads. Recent modeling confirmed that the area that benefited from the reduced nitrogen loading is southern Budd Inlet, and central Budd Inlet is responding to something else that could be affecting all of South Sound.

The model also provides interesting insights into potential management actions. For example, model predictions indicate that tidal cycles strongly influence DO levels in Budd Inlet. The amount of water that enters and exits Budd Inlet varies with the phase of the moon, and the lowest DO levels coincide with the lowest water exchanges, which are easily predictable. Predictability helps sharpen management.

IDENTIFICATION OF HEAVY RAINFALL PATTERNS FROM PEAK FLOOD FLOW RESPONSE IN SMALL THURSTON COUNTY STREAMS

Nadine Romero[1] *and Mark Biever*[2]
[1]Thurston County Environmental Health, [2]Thurston County Water and Waste Management

We have identified 6 precipitation patterns which appear to control peak flood flow pulses in small Thurston County streams. Using the Olympia Airport precipitation record we discovered that all 6 heavy rainfall scenarios have occurred within the last decade (1998-2009) and some more than once. The previous five decades of the Olympia rainfall record have only been punctuated by one to three of the identified scenarios per decade.

These observations came out of our efforts to compute average daily stream flows from automated river stage data collected by Thurston County in the last decade where approximately one-half to 1 million pieces of automated data have been collected and stored for *each river system*. Annual reports of stream flows are currently being developed for all Thurston County monitored streams. Heavy rainfall precipitation patterns are identified as follows:

1. Early heavy rainfall (> 3-inch daily storm events) in October (Horton Overland Flow), example:
   4.14 - inch storm event – October 20, 2003

2. Five or six consecutive days of greater than 1-inch storm events punctuated by a greater than > 2.5-inch storm event in the same series, example:

2006:	Nov 2	Nov 3	Nov 4	Nov 5	Nov 6	Nov 7
	1.08"	1.02"	1.50"	1.88"	4.31"	1.02"

3. Two or more consecutive days of > 2.0 inch daily storm events, example:

2007:	Dec 2	Dec 3
	2.12"	3.19"

4. Greater than > 4 inch daily storm events, example:
   January 7, 2009 4.82 inches
   November 6, 2006 4.31 inches

5. Three or more consecutive months of at or greater than >11 inch monthly totals (ground water flooding), example:

	Nov	Dec	Jan	Feb
1998-1999	15.28	12.99	12.25	15.5
2001-2002	13.01	11.86	11.42	

6. A greater than, > 15 inch monthly total, example:
   November of 2006 – 19.68 inches
   February of 1999 – 15.5 inches
   November of 1998 – 15.28 inches

The condition of 'rain on snow' events which can exacerbate streams to flood flow stage (Dec 2-3, 2007 flooding) is more anecdotal but clearly remains yet another pattern for peak floods. The data suggests that heavy to severe rainfall patterns have increased in frequency during the last decade versus the previous 50 years of record for the Olympia Airport despite drought years.

	Frequency					
	"Last Decade"					
Condition	2009-1998	1990-97	1980-89	1970-79	1960-69	1950-59
1	X					
2	X		X		X	
3	X			X		X
4	X,X,X					
5	X,X			X	X,X	X
6	X,X,X	X				X

MAPPING THE CONCENTRATION OF *ALEXANDRIUM CATENELLA* CYSTS IN THE SURFACE SEDIMENTS OF QUARTERMASTER HARBOR

Mitchell Schatz, Julie Masura, and Cheryl Greengrove - University of Washington Tacoma

Alexandrium catenella is a marine dinoflagellate that produces saxitoxin, which when bio-accumulated in marine filter-

feeders can result in Paralytic Shellfish Poisoning (PSP) for mammals that ingest the shellfish. Blooms of *A. catenella* occur at various locations around the world, including Puget Sound and have resulted in shellfish harvesting closures locally. *A. catenella* spends part of its lifecycle as a benthic cyst in the sediment and has been shown to germinate when temperatures exceed 13-14^{o}C in Puget Sound. In 2005, a NOAA/ECOHAB study of Puget Sound found that Quartermaster Harbor (QMH), on the south end of Vashon Island, has the highest concentration of *A. catenella* cysts of any surface sediments in Puget Sound. The NOAA/ECOHAB distribution study was based on one sample in the bay. In 2008, we did a follow-on cyst mapping study, courtesy of funding from the Russell Family Foundation, by collecting and analyzing 24 surface sediments samples throughout QMH. These samples were processed, stained, and counted for *A. catenella* cysts. Sediment samples were also analyzed for particle size and total organic carbon (TOC). A map was created showing the relative concentrations of *A. catenella* cysts in the surface sediments of QMH. We found a higher concentration of surface sediment cysts in the inner bay of QMH than the outer bay. Lowest concentrations of cysts were in the outer bay near the mouth of the harbor. Knowledge about the distribution of cysts in the bay could help shellfish managers avoid high shellfish risk areas for harvesting.

PUGET SOUND SEABIRD SURVEY: EMPOWERING BIRD-WATCHERS TO CONTRIBUTE NEEDED DATA ON WINTERING SEABIRDS

Adam Sedgley - Seattle Audubon

Organized by Seattle Audubon, the Puget Sound Seabird Survey (PSSS) is a demonstration of the utility and value of citizen-driven scientific surveys. PSSS empowers volunteer bird-watchers to gather valuable data on wintering seabird populations in Puget Sound. Over fifty locations in Island, King, Pierce, Snohomish and Thurston counties are currently surveyed within the same four-hour window on the first Saturday of each month, October through April, thus creating synchronized "snapshot" of seabird densities on over 90 miles of nearshore saltwater shoreline.

The Puget Sound Seabird Survey addresses known gaps in our understanding of local wintering seabird populations: it is the only land-based or multi-month seabird survey in central or south Puget Sound. In addition, PSSS is the only regional citizen science project that employs a rigorous distance sampling technique to address detectability. This statistical strength has been officially supported by the Chief Scientist at the Washington Department of Fish and Wildlife, which contributes financially to the program, and the governor-appointed Executive Director of the Puget Sound Partnership. The program advising committee is composed of preeminent researchers, scientists, and statisticians from local agencies and academic institutions.

Seattle Audubon created this project to be replicable and scalable. Currently in the surveys second year, Seattle Audubon continues to seek additional areas of ecological interest to expand the program, while maintaining statistically sound data. Volunteer surveyors are recruited from local bird-watching and wildlife biology communities and receive thorough in-the-field training on the protocol. All of the PSSS materials, e.g. background, protocol, recording form and teaching aids, are hosted online (http://seattleaudubon.org/science.cfm?id=1168) and data is entered through an intuitive online interface.

The PSSS dataset can be made available to agencies and organizations that will analyze and use it to benefit bird conservation or ecosystem health. Seabirds are a key component of the ecosystem and excellent indicators of the health of Puget Sound, the proverbial "canary in the coalmine." Seattle Audubon's primary goal is to build a sustainable and scientifically valuable program that is relevant on the larger stage of conservation and policy.

QUARTERMASTER HARBOR WATER PROPERTIES

Benjamin Shetterly and Cheryl Greengrove - University of Washington Tacoma

Historical and scientific indications of neurotoxin-producing phytoplankton species in Puget Sound have led to interest in these organisms' environmental preferences, transport, historical spread and potential hotspots. Near Puget Sound's Vashon Island, Quartermaster Harbor (QMH) sediments have been identified as containing a significantly high population of cysts of *Alexandrium catenella*, compared to other Puget Sound sites, and shellfish harvests are closed often due to possibility of Paralytic Shellfish Poisoning (PSP). To better understand the environmental factors that may have led to this higher cyst concentration, the University of Washington Tacoma has conducted undergraduate research on QMH waters, sediments and plankton. This study focuses on the temporal and spatial trends in the physical and chemical properties of QMH waters and relates them to physical forcing conditions, such as seasonal weather patterns and tides, and estuarine biological processes. From October 2006 to February 2009, CTD water property profiles (temperature, salinity, density, dissolved oxygen, fluorescence (chlorophyll a), and transmissivity) and discrete oxygen, chlorophyll a, dissolved nutrient and phytoplankton samples were collected, almost monthly. The CTD profiles were developed into contour plots, to allow visual cross-sections of properties to be analyzed. Notable results include contour plots of density, temperature and salinity in the warmer months, which show stratification in the inner harbor stations. Fluorescence and dissolved oxygen contour plots also reveal the productivity of QMH waters near the pycnocline during the phytoplankton growing season. Quartermaster Harbor, a relatively protected harbor in the Puget Sound Main Basin, has a number of estuarine characteristics in common with South Puget Sound bays, and the water proper-

ties relate closely to plankton growth trends, including the suitability of its waters to *A. catenella* populations.

USING METALLOTHIONEINS IN BENTHIC MARINE WORMS AS BIOINDICATORS OF METAL TOXICITY IN PUGET SOUND

Giovannina Souers and Jim Gawel - University of Washington Tacoma

Population growth and industrialization over the last 100 years have taken a toll on the health of Puget Sound. On the basis of pollutant concentrations in sediments in Puget Sound, the Washington Department of Ecology has labeled over 100 sites as contaminated. Sediment is the major compartment for metal storage in aquatic environments and although metal concentrations in sediments have been studied well in this area, there has been very little research connecting the levels of metals in our sediments to physiological effects on the benthic community. Research on metallothioneins (a class of proteins important for the detoxification of heavy metals in marine organisms) is a first step in identifying how higher then normal levels of copper, lead, mercury, and other metal pollutants are affecting the benthic communities. In this study benthic marine worms are being collected from historically polluted Puget Sound sites between Tacoma and Seattle. City of Tacoma - Environmental Services, Citizens for a Healthy Bay (Tacoma) and Department of Ecology are all helping in the collection of worms from around the Sound. Worm communities from each site will be combined and then tested for metallothionein levels. Sediments from these sites will also be tested for heavy metal concentrations and data will be analyzed for statistical correlations between metals levels and metallothionein production. Preliminary data and methodology for this research will be presented.

TORRENT SALAMANDER MOVEMENT ECOLOGY: PERSPECTIVE ON A "SEDENTARY" SPECIES

Julie Tyson and Marc Hayes - Washington Department of Fish and Wildlife

Torrent salamanders (genus *Rhyacotriton*) are potentially characterizable as the most sedentary amphibians in the Pacific Northwest. Maximum reported movements for any life stage span only 22 m. In the course of a manipulative study examining amphibian response to different levels of shade, we opportunistically obtained 60 captures of larval Olympic torrent salamanders (*R. olympicus*) that had escaped from stream enclosures. Within the same year (season), 34 unique individuals moved distances ranging up to 122 m over intervals spanning 2 to 119 days. Thirteen of these animals moved 2 to 100 m further than the maximum reported for any *Rhyacotriton* life stage. Further, 4 unique individuals recaptured over intervals of 352 to 415 days in different calendar years moved 2 to 93 m. Though our data consist of escapees from stream enclosures, they illustrate that larval torrent salamanders are capable of moving distances substantially greater than previous reports. Moreover, design of all previous studies that have some ability to describe movements in *Rhyacotriton* have not attempted recaptures outside a limited footprint, which makes underestimation of movement scale unavoidable. These findings strongly suggest that movement scale in *Rhyacotriton* merits re-investigation.

INDICATORS TO ASSESS BIODIVERSITY IN WASHINGTON STATE: A CONCEPTUAL FRAMEWORK LINKING HUMANS AND NATURAL RESOURCES

Steven Walters[1], *John Marzluff*[1], *and Lynn Helbrecht*[2]
[1]University of Washington, [2]Washington Biodiversity Council

The topographic and climatic heterogeneity of Washington State, combined with its coastal position on the Pacific Ocean, make it a biologically diverse region. Tasked with conserving our state's native plants, animals, and ecosystems for current and future generations, the Washington Biodiversity Council is developing a set of indicators to assess the status of "the full range of life in all its forms." Aimed at providing guidance to legislators, policy and decision makers, as well as engaging Washington's citizenry on the importance and stewardship of biodiversity, the indicators encompass the native species and ecosystems of the state, their contributions to human quality of life, and the public and private institutional frameworks in place that support biodiversity.

We present an overarching conceptual framework for our draft indicators: this framework explicitly considers the interactions between the elements of biodiversity (from genetic diversity to landscape patterns) and the ecologically and human-driven processes that impact and support biodiversity. The framework encompasses a set of high-level indicator categories that reflect these human-biophysical linkages and capture the status of biodiversity and human impacts. Each category, in turn, is represented via a set of quantitative metrics. These draft indicators represent the causal linkages between elements of biodiversity (e.g., pollinator insects and birds), ecological processes (e.g., plant productivity), and human systems that support (e.g., through pollinator conservation efforts) and are supported by (e.g., through agricultural and vinicultural productivity) these ecological interactions. In coordination with other analogous efforts across Washington (including those of the Puget Sound Partnership), the indicators will provide a means of assessing the status and trends of structures and functions that are important to biodiversity, emphasizing the intrinsic interdependence between humans and the natural resources of the state.

SEX-SPECIFIC IDENTIFICATON OF *ASCAPHUS TRUEI* AT MATURITY

Frithiof Waterstrat[1], April Barreca[2], and Marc Hayes[1]
[1]Washington Department of Fish and Wildlife, [2]Central Washington University

The Coastal Tailed Frog (*Ascaphus truei*) is headwater stream-associated amphibian inhabiting riparian forests from British Columbia, Canada to Northwestern California, USA. Undoubt-

edly the most distinctive feature of tailed frogs, and a characteristic unique within the Order Anura, is the possession of an external copulatory organ or "tail" present on males. Examination for a cloacal tail is the typical mode of field determination of sex in male tailed frogs. As males mature they also exhibit secondary sexual characteristics: nuptial pads; textured patches specific to the chest, chin, and digits of the front feet; and enlarged forearms. Determination of sex in females typically represents a default (absence of the male pattern). We are interested in the concordance between external sex determination and presumably more precise determination based on gonadal examination. We had concern that using a smaller male default size might overestimate mature female numbers, or alternatively using mean adult size might underestimate male numbers and overestimate female numbers. We determined the sex of over 300 frogs by external examination from collections made at seven localities during late summer/early fall 1984 and 1985, scoring or measuring the aforementioned sexual characteristics. We then dissected these frogs to verify gender, assessed gonad development and measured gonad size to evaluate sexual maturity.

Identification of maturity from plotted gonad-to-body-size data by visual examination versus using piece-wise regression differed for males and females. Regression fit of all female data has a high variance, the largest source of which likely reflects biennial reproduction, though pooling localities also contributes. Partitioning reproductive from non-reproductive adult females results in estimates of size at maturity for the two methods converging. Our continuing analyses of these data seek to minimize variance in estimates in size at maturity for both sexes.